

## **SIMULATION OF THE HYSTERESIS VOLTAGE CONTROL TECHNIQUE IN THE PV BASED DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY IMPROVEMENT WITH INDUCTION MOTOR DRIVE**

**SYED YASSER ALI<sup>1</sup> & K. SUNEETA<sup>2</sup>**

<sup>1</sup>M.Tech Student, Department of Electrical and Electronics Engineering, Anurag Group of Institutions,  
Ghatkesar, Telangana, India

<sup>2</sup>Associate Professor, Department of Electrical and Electronics Engineering, Anurag Group of Institutions,  
Ghatkesar, Telangana, India

### **ABSTRACT**

Voltage sag and swell in the average and low electrical energy distribution grid are measured to be the nearly all frequent type of power quality problems base on top of topical power quality study. Their impact on responsive loads is severe. To equipment these situation, convention power equipment are utilize. Dynamic Voltage Restorer (DVR) is modified power equipment to be utilized to improve voltage stability. The future concept is PV cell as the Input to inverter and the presentation of the DVR know how to be implement with squirrel cage Asynchronous motor drive. This paper present the hysteresis voltage control technique base on voltage reference signal, for generation of switch pulse for inverter of dynamic voltage restorer and the future system is design in MATLAB software, results show that the how dynamic voltage restorer is useful for power quality development in distribution system.

**KEYWORDS:** Dynamic Voltage Restorer, Photovoltaic's, Induction Motor

### **INTRODUCTION**

Nowadays, since of large use of sensitive and nonlinear loads in electrical power systems and the fast growth of renewable energy source, the power quality problems are especially important. Power quality is one of the major concerns in the present power system environment. The most regular power quality situation is voltage dip and swell, and harmonic contented and so on. Because of the power quality disturbance, the several industrial consumers are strongly affected. The situation like-voltage sag and swells, harmonic contented etc and so on, major effect on greatly susceptible load is well known. Even the conventional conceptions suffer with effective controller problems. To tackle these situations, convention power apparatus are utilized. In 1995 the concept of convention power is first explain by Hingorani [1]. The thought of custom power (CP) identify with the exploitation of electronic controller for power system network. The CPD devices are either connected in series or in shunt or combination of both. The aforementioned every unit has its particular profits and constraint.

Dynamic Voltage Restorer (DVR) is a modified power apparatus that is utilize to enhance and mitigate the voltage. The principle of the DVR is utilized to inject the voltage in series and in synchronism with the normal voltages with a goal to compensate voltage influence.

Dynamic voltage restorer is on the whole suitable to protect load from short length electrical energy dip and swell. When a short circuit happens in a power system network, an unexpected voltage dip will show on nearby feeders by means of a DVR introduced on a load feeder, the line voltage is restored to its regular level within the rejoiner time of a few milliseconds. Hence power disruption is avoided.

This paper presents the hysteresis electrical energy control technique used for controlling the PV based dynamic voltage restorer and generation of switch pulse (gate pulses) for inverter of dynamic voltage restorer with Asynchronous drive. The control method based on voltage reference signal and dynamic voltage restorer is useful for power quality development in distribution system.

The hysteresis controller mainly requires two voltage signals, one is from supply side voltage signal and another is from booster transformer which is voltage injected by dynamic voltage restorer. The controller compares these two signals and according to these signals switching pattern is established.

## **DYNAMIC VOLTAGE RESTORER**

Among the power quality problems (sags, swells, harmonics...) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. The DVR is recognized as successful sort of custom power unit due to its following advantages:

- It has capacity to manage the active power flow.
- It has less cost compared with others.
- It requires less maintenance
- It has higher energy capacity.
- DVR is more minor in size and expenses less compared with the DSTATCOM

DVR recompenses the voltage dip, voltage swell; it can additionally include different features for example power factor correction and harmonics elimination. [2]

DVR is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also add other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations.

Dynamic voltage restorer is overall suited to secure susceptible or delicate load from short span voltage dips and swells. Whenever a short circuit happens in a power system network, a sudden voltage dip will show on nearby feeders. With a DVR introduced on a load feeder, the line voltage is restored to its normal level within the reaction time of a few milliseconds. Hence power interruption is avoided

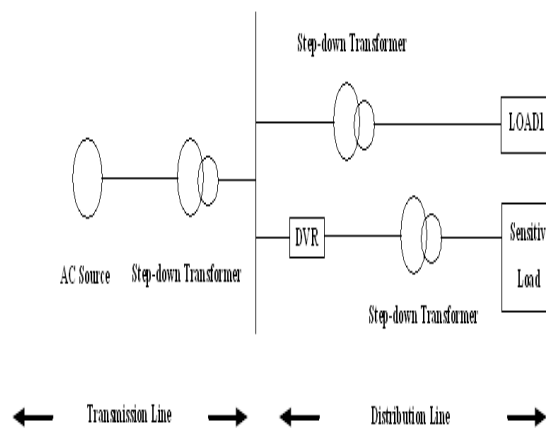


Figure 1: Compensation by DVR for Sensitive Load

## HYSTERESIS VOLTAGE CONTROL TECHNIQUE

Technique applied in this paper is based on voltage error and is non linear control method. Hysteretic control, also known as bang-bang control or ripple regulator control, maintains the converter output voltage within the hysteretic band centered about the reference voltage. The hysteresis voltage control technique is used for controlling the dynamic voltage restorer and generation of switching pulses (gate pulses) for the inverter of DVR.

The hysteretic-controlled regulator is popular because of its inexpensive, simple and easy-to-use architecture. The greatest benefits of hysteretic control are that it offers fast load transient response and eliminates the need for feedback-loop compensation. The other well known characteristic is the varying operating frequency. However, the regulation inaccuracy issue of the hysteretic-controlled converter is almost unknown to engineers. Until now, research on hysteretic regulators has mainly focused on transient analysis and transient modeling.

The hysteresis controller mainly requires two voltage signals, one is from supply side voltage signal and another is from booster transformer which is voltage injected by dynamic voltage restorer. The controller compares these two signals and according to these signals switching pattern is established.

It consists of a comparison between the output voltage and the tolerance limits around the reference voltage, while the output voltage is between upper limit and lower limit.

Hysteresis band voltage control is used to control load voltage and determine switching signals for inverter switches. (It terminates the ON-pulse if the ramp voltage exceeds the reference voltage by a certain amount and turns the switch back ON when the ramp falls below a certain threshold slightly lower than the reference voltage. It is therefore often called a “bang-bang” regulator). If there is a sudden line or load transient, it can react by either turning OFF completely for several pulses in succession, or by turning ON fully.

There are bands above and under the reference voltage. If the difference between the reference and inverter voltage reaches to the upper (lower) limit, the voltage is forced to decrease (increase). The following relation is applied where HB and  $f_c$  are Hysteresis band and switching frequency, respectively.

$$T1 + T2 = T_c = 1/f_c$$

The reference three-phase voltage signals generated is compared by the three-phase DVR output voltages to generate the switching pluses of the IGBTs independently.

The hysteresis band HB is the difference between  $V_H$  and  $V_L$  ( $HB = V_H - V_L$ ). The hysteresis band is inversely proportional to the switching frequency of IGBTs. It also determines the quality of the DVR voltage and consequently the load voltage. The quality of the DVR and load voltage is measured using the well-known term Total Harmonic Distortion (THD) which is given as:

$$THD (\%) = 100 \times \frac{\sqrt{\sum_{k=2}^n V_K^2}}{V_1}$$

Where,

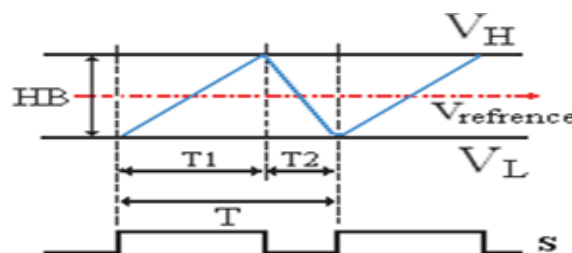
$K$  is the harmonic order.

$n$  is the total number of harmonics.

$V_1$  is the fundamental component of the voltage.

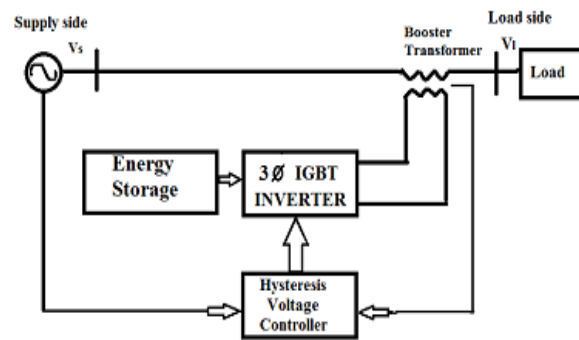
Hysteresis voltage control technique can be operated in two ways they are

- Unipolar PWM methods.
- Bipolar PWM methods.



**Figure 2: Hysteresis Band Voltage Control**

Following figure explains the main control diagram of dynamic voltage restorer with hysteresis voltage controller. It mainly consists of three phase IGBT inverter, Energy storage, booster transformer and the hysteresis voltage controller. The hysteresis controller mainly requires two voltage signals, one is from supply side voltage signal and another is from booster transformer which is voltage injected by dynamic voltage restorer. The controller compares these two signals and according to these signals switching pattern is established.



**Figure 3: Structure of DVR with Hysteresis Voltage Control Technique.**

The control technique applied in this paper is based on voltage error and is non linear control method. It consists of a comparison between the output voltage and the tolerance limits ( $V_H, V_L$ ) around the reference voltage, While the output voltage is between upper limit and lower limit, no switching occurs and when the output voltage increases to the upper limit (lower band) the output voltage is decreased (increased).

## PHOTOVOLTAIC SYSTEMS

Converting solar energy into electrical energy by PV installations is the most Photovoltaic cells produced by the majority of today's most large producers are mainly made of crystalline silicon as semiconductor material.

Solar photovoltaic modules which are a result of combination of photovoltaic cells to increase their power are highly reliable, durable and low noise devices to produce electricity. The sun is the only resource that is required for the operation of PV systems, and its energy is almost inexhaustible. Typical photovoltaic cell efficiency is about 15%, which means it can convert 1/6 of solar energy into electricity. Photovoltaic systems produce no noise, there are no moving parts and they do not emit pollutants into the environment. Taking into account the energy consumed in the production of photovoltaic cells, they produce several tens of times less carbon dioxide per unit in relation to the energy produced from fossil fuel technologies.

Photovoltaic cell has a lifetime of more than thirty years and is one of the most reliable semiconductor products. Most solar cells are produced from silicon, which is non-toxic and is found in abundance in the earth's crust.

Photovoltaic systems (cell, module, and network) require minimal maintenance. At the end of the life cycle, photovoltaic modules can almost be completely recycled. Photovoltaic modules bring electricity to rural areas where there is no electric power grid, and thus increase the life value of these areas. Photovoltaic systems will continue the future development in a direction to become a key factor in the production of electricity for households and buildings in general. The systems are installed on existing roofs and/or are integrated into the façade. These systems contribute to reducing energy consumption in buildings. Also, photovoltaic technology, as a renewable energy source, contributes to power systems through diversification of energy sources and security of electricity supply.

By the introduction of incentives for the energy produced by renewable sources in all developed countries, photovoltaic systems have become very affordable, and timely return of investment in photovoltaic systems has become short and constantly decreasing. In recent years, this industry is growing at a rate of 40% per year and the photovoltaic technology creates thousands of jobs at the local level.

## ADVANTAGES OF PHOTOVOLTAIC TECHNOLOGY

Photovoltaic systems offer substantial advantages over conventional power sources:

- **Reliability:** Even in harsh conditions, photovoltaic systems have proven their reliability. PV arrays prevent costly power failures in situations where continuous operation is critical.
- **Durability:** Most PV modules available today show no degradation after ten years of use. It is likely that future modules will produce power for 25 years or more.
- **Low Maintenance Cost:** Since PV systems require only periodic inspection and occasional maintenance, these costs are usually less than with conventionally fueled systems.
- **No Fuel Cost:** since no fuel source is required, there is any cost associated with purchasing, storing, or transporting fuel.
- **Reduced Sound Pollution:** Photovoltaic systems operate silently and with minimal movement.
- **Photovoltaic Modularity:** PV systems are more cost effective than bulky conventional systems. Modules may be added incrementally to a photovoltaic system to increase available power.
- **Safety:** PV systems do not require the use of combustible fuels and are very safe when properly designed and installed.
- **Independence:** Many residential PV users cite energy independence from utilities as their primary motivation for adopting the new technology.

## ASYNCHRONOUS MOTOR

An induction motor (IM) is a type of asynchronous AC motor where power is supplied to the rotating device by means of electromagnetic induction. Other commonly used name is squirrel cage motor due to the fact that the rotor bars with short circuit rings resemble a squirrel cage (hamster wheel). An electric motor convert's electrical power to mechanical power in its rotor.

There are several ways to supply power to the rotor. In a DC motor this power is supplied to the armature directly from a DC source, while in an induction motor this power is induced in the rotating device. An induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Induction motors are widely used, especially poly phase induction motors, which are frequently used in industrial drives.

The Induction motor is a three phase AC motor and is the most widely used machine. Its characteristic features are

- Simple and rugged construction
- Low cost and minimum maintenance
- High reliability and sufficiently high efficiency
- Needs no extra starting motor and need not be synchronized

- An Induction motor has basically two parts – Stator and Rotor.

The Stator is made up of a number of stampings with slots to carry three phase windings. It is wound for a definite number of poles. The windings are geometrically spaced 120 degrees apart. Two types of rotors are used in Induction motors - Squirrel-cage rotor and Wound rotor

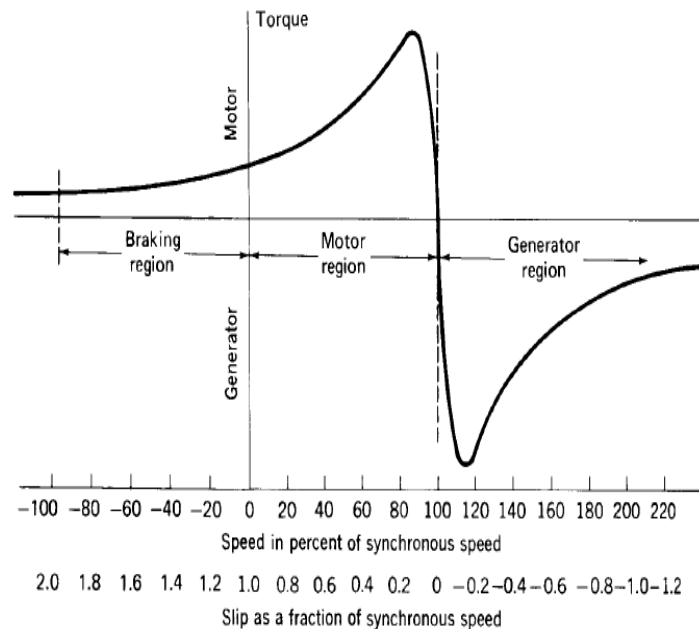


Figure 4: AC Induction Motor Speed-Torque Characteristic

## THE PROPOSED SYSTEM

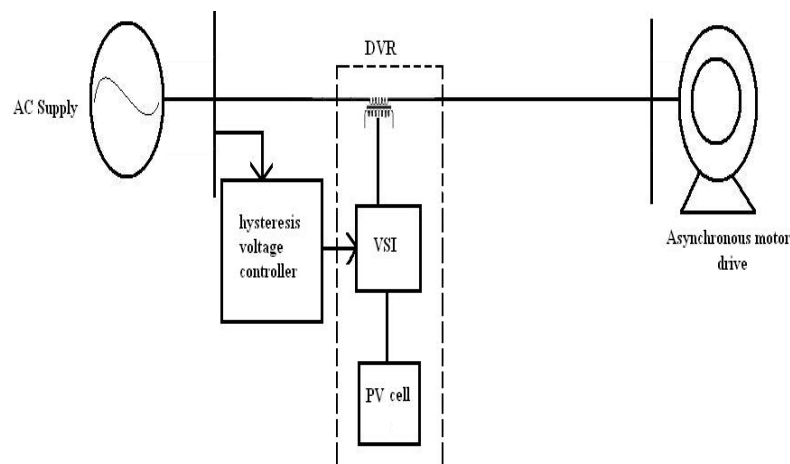


Figure 5: The Proposed System.

A Dynamic Voltage Restorer (DVR) is a series connected solid state facts device composed of a converter, a dc storage capacitor, and a transformer connected in series with a distribution bus bar that injects voltage into the system in order to regulate the load side voltage. Its configuration is similar to that of SSSC however, the control techniques are different. Also, a DVR responds fast (less than 1/4 cycle) and thus employs PWM converters using IGBT or IGCT devices.

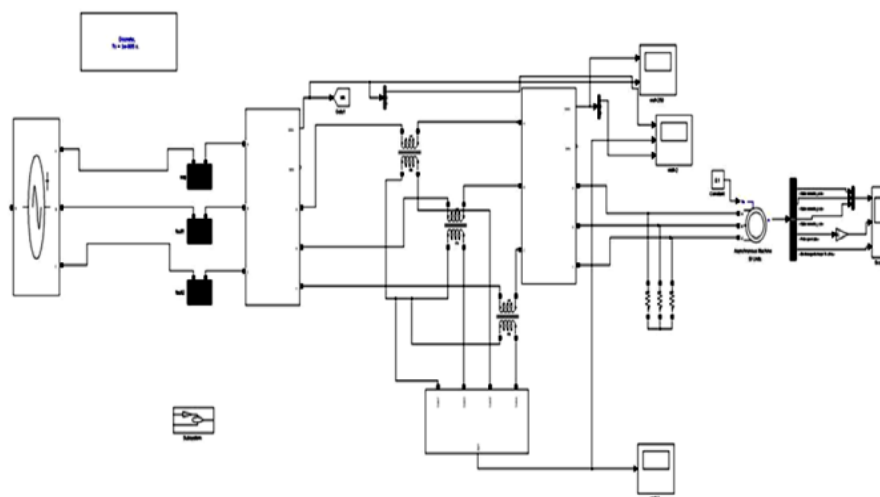
Typically, DVRs are made of modular design with a module rating of 2 MVA or 5 MVA. A DVR typically requires less than one-third the nominal power rating of the UPS. In this concept the hysteresis voltage control technique is used for controlling the dynamic voltage restorer and generation of switching pulses (gate pulses) for the inverter of DVR. DVR has several limitations and some of them are

- DVR has a limited current conduction and voltage injection capability which is due to such design of DVR to keep its cost low as well as to reduce the voltage drop across it in standby mode.
- In order to reduce the cost of DVR, the energy storage size of DVR is kept low. Due to voltage dips, the stored energy can deplete fast and therefore to avoid load tripping due to insufficient stored energy, an adequate control is required.

To overcome above problem battery or energy storage is replaced by PV system which can supply continuous power supply to DVR during day loads which has high peak of industrial and sensitive loads during daytime. In addition to PV system an asynchronous motor load is added to evaluate as high load in MATLAB.

In MATLAB faults such as voltage swells and voltage sag are artificially created by using sag and swell generators. In MATLAB swell generated is duration of 0.5 to 1 sec and amplitude of 800v. Sag generated is duration of 1.5 to 2 sec. This fault supply is sent to the hysteresis voltage controller for generation of switching pulses (gate pulses) for the inverter of DVR. Hence switching pulses are applied to each MOSFET in VSI hence turning on VSI. VSI generates compensating voltage in according to duration of fault from dc source battery. This voltage is filtered through passive LC filter so as filter any harmonics generated by power electronic devices. This compensating voltage is injected by injection transformer of ratio 1:1 into three phase supply lines. Hence fault is compensated.

## MATLAB/SIMULIK RESULTS



**Figure 6: Simulink Diagram of Hysteresis Voltage Control Technique in PV Based Dynamic Voltage Restorer for Power Quality Improvement with Squirrel Cage Asynchronous Motor Drive**



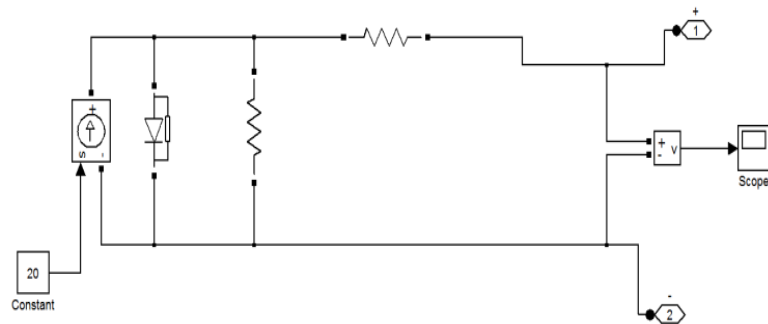


Figure 7: Simulink Diagram of PV Cell Equivalent Circuit

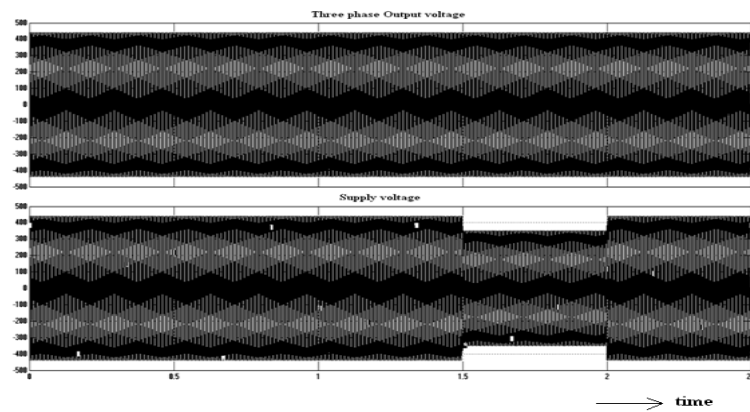


Figure 8: Three Phase Output and Supply Waveform

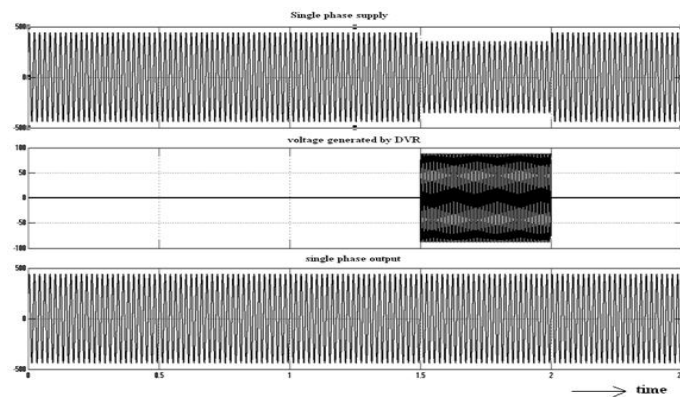


Figure 9: Single Phase Output Waveforms

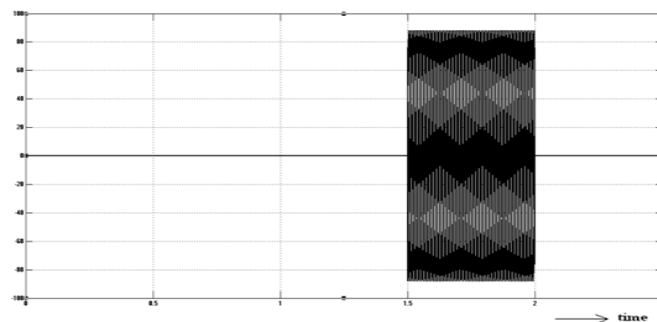
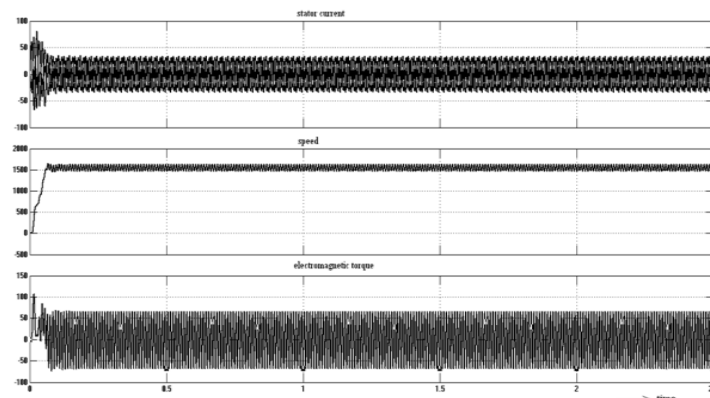


Figure 10: Compensating Voltage Generated by DVR



**Figure 11: Motor Parameters Waveforms**

## CONCLUSIONS

Many industries consist of large number of power electronics devices and energy resourceful apparatus these are more susceptible to the unbalance in the input supply voltage. Now a day's issues of power quality are very important for customer and utility also. So for this custom power device, Dynamic Voltage Restorer (DVR) with PV system is used to mitigate these power quality problems, also it shows that the hysteresis voltage control technique is very good technique for dynamic voltage restorer as it plays an important role in mitigation of voltage sag, voltage swell, etc. for Asynchronous motor load.

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## AUTHOR'S DETAILS



Syed Yasser Ali, graduated from Kamala institute of technology and science, Huzurabad, Karimnagar district affiliated to J.N.T. University, Hyderabad in the year 2012, and he is currently pursuing his post graduation in the specialization of Electrical Power System from the Anurag group of institutions (formerly CVSR college of engineering) affiliated to J.N.T University Hyderabad



DR. K. SUNEETA, graduated from J. N. T. University, Hyderabad in the year 2001, and she has done her Post Graduation in the specialization of Electrical Power Engineering from the same college J. N. T. University, Hyderabad in the year 2005, now and she has done her PhD in the area of power system deregulation from J. N. T. University, Hyderabad.

